# Characterization of the Front-End Electronics for the Pixel-Strip Module of the Phase 2 CMS Tracker

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Transition from LHC to HL-LHC

The Large Hadron Collider (LHC) has so far delivered 20fb^{-1} of 13TeV proton-proton collisions. It will operate till the 2020s, when it will upgraded to the High Luminosity LHC (HL-LHC). The HL-LHC will operate with 14TeV proton-proton collisions, increasing the instantaneous luminosity from the current 1.2x10^{34}cm^{-2}s^{-1} to 5x10^{34}cm^{-2}s^{-1}. This will enable accelerator to deliver 3000fb^{-1} over the course of the project, a factor of 10 greater than physicists hope to achieve with the LHC. However the greater luminosity will come at the price of higher radiation and a higher number of collisions per bunch-crossings.
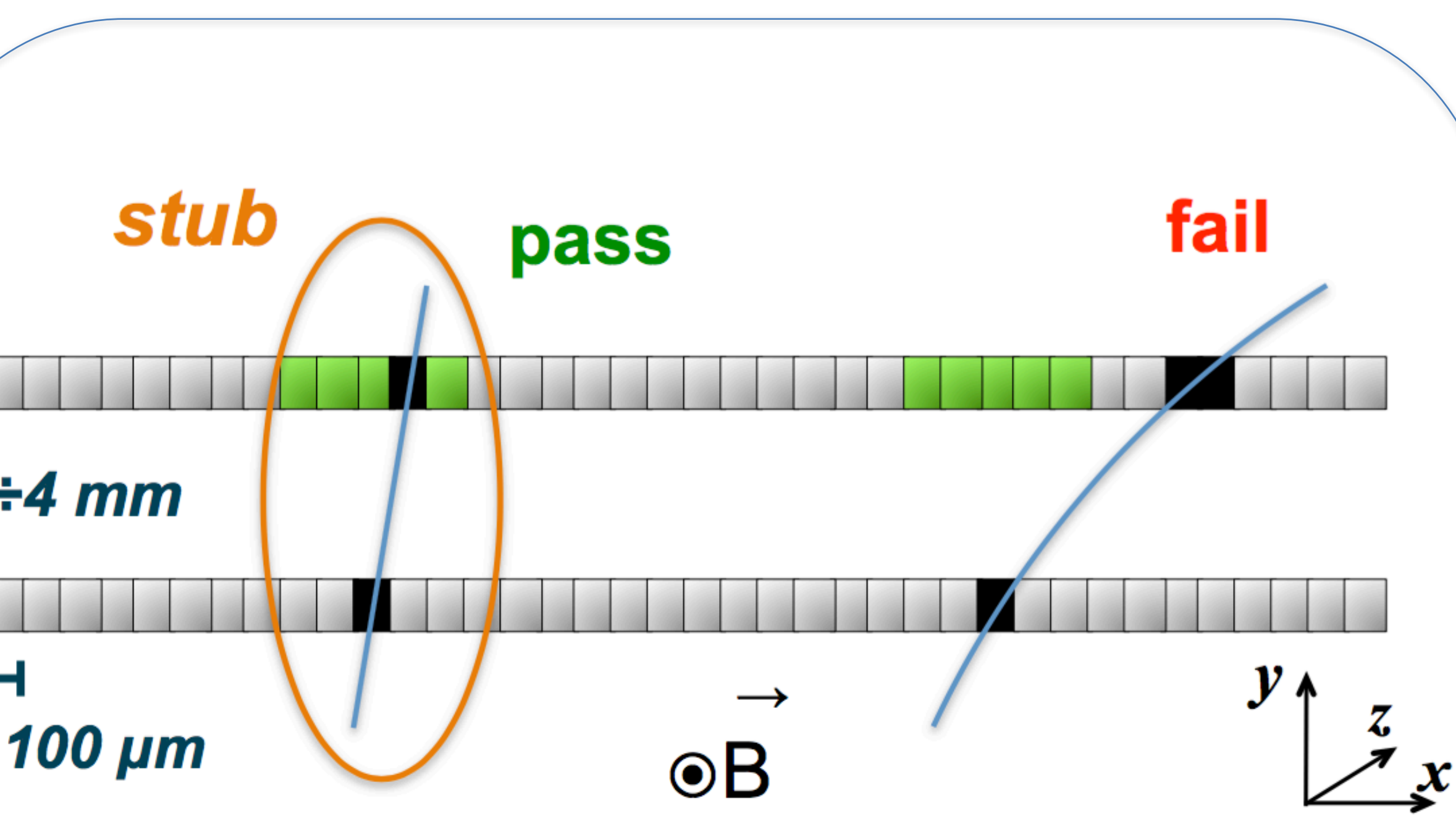

Illustration of Stub Finding: When a pixel in a PS sensor receives a hit, that pixel's MPA will search a narrow region of strips for a second hit. Because high transverse momentum (high p$_T$) particles bend less in the CMS magnetic field, finding a hit in the search region of the strip module points to a high p$_t$ candidate. After correlating two hits, the PS module outputs these stubs at a frequency of 40MHz.
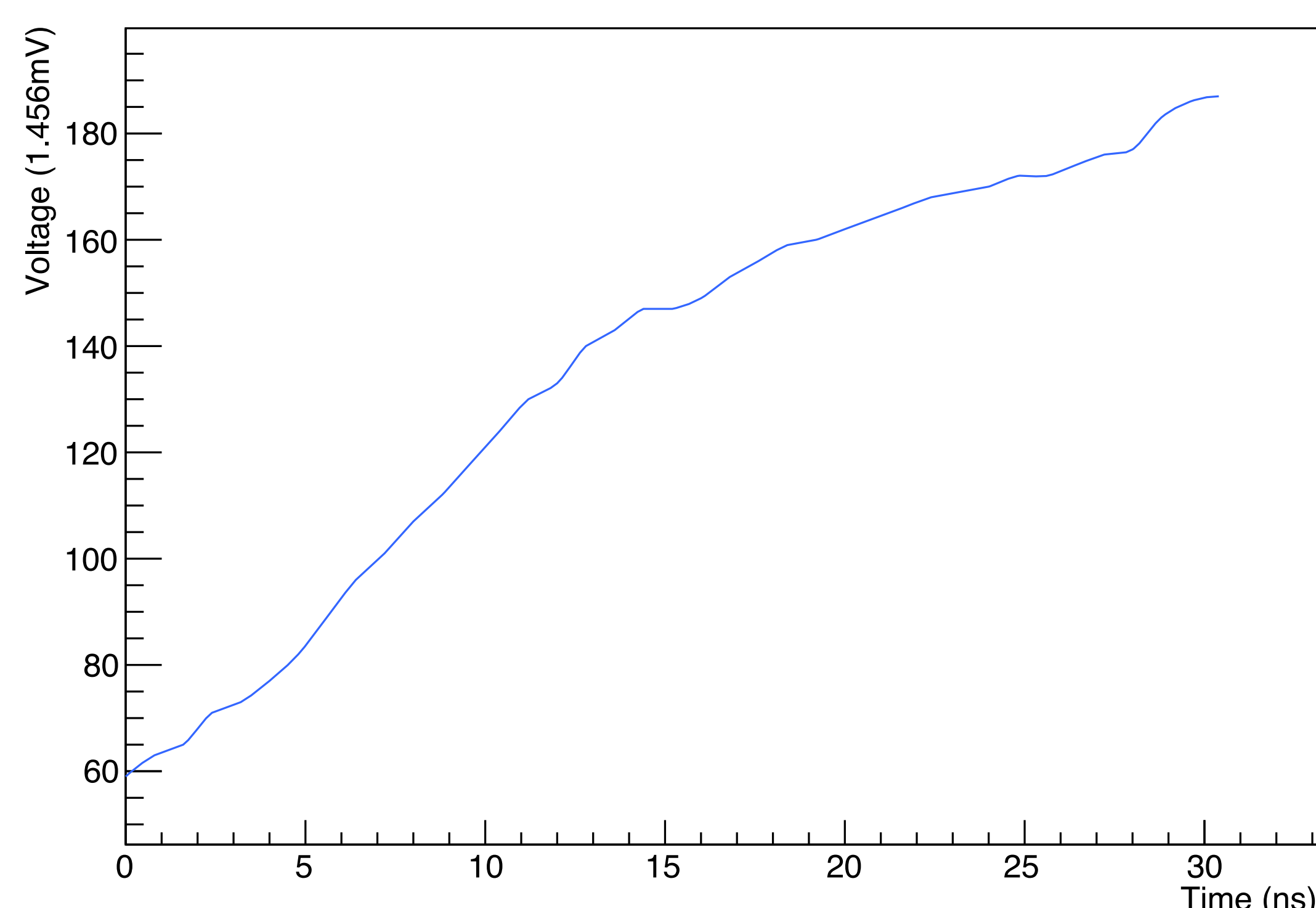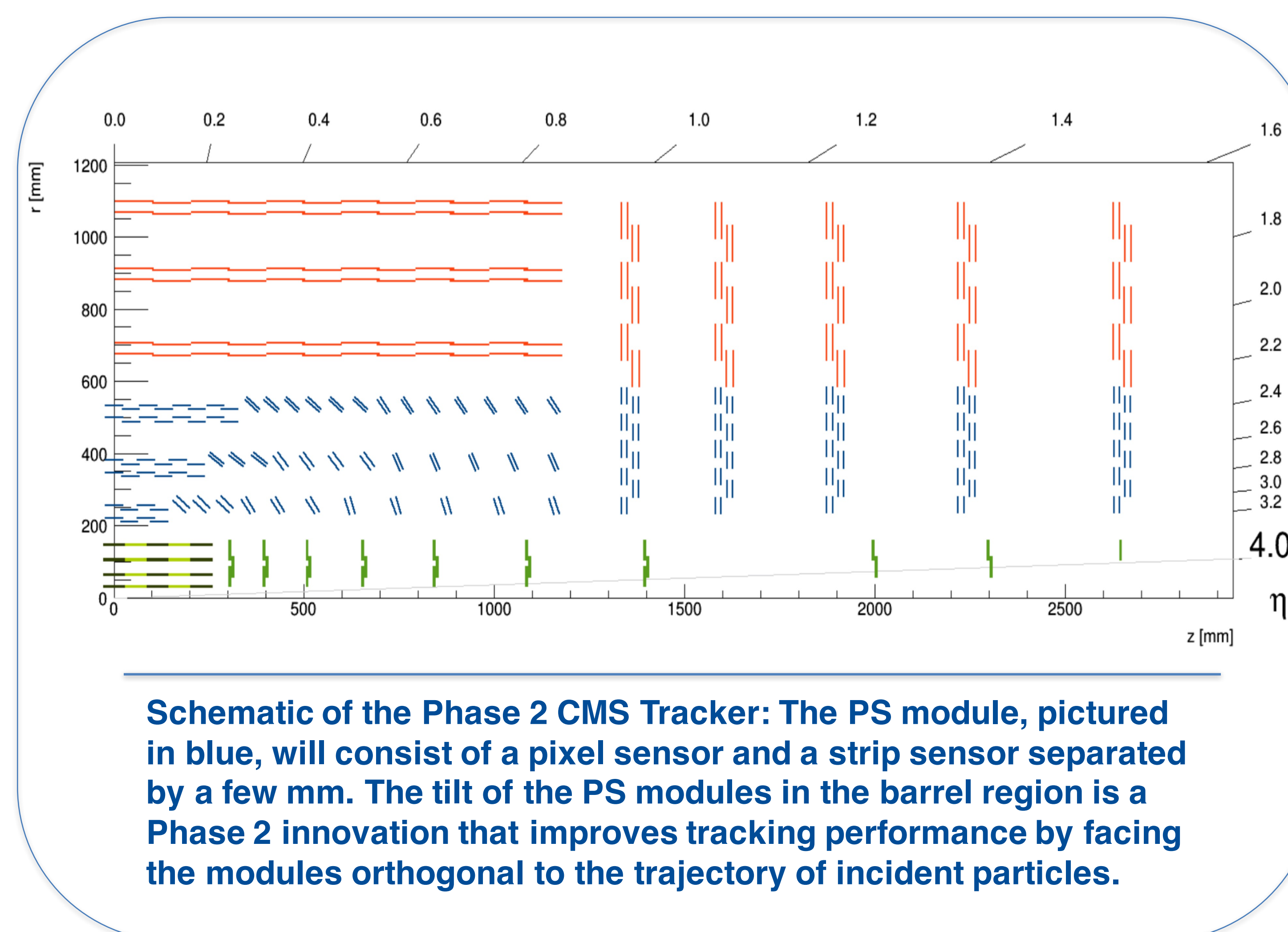
Schematic of the Phase 2 CMS Tracker: The PS module, pictured in blue, will consist of a pixel sensor and a strip sensor separated by a few mm. The tilt of the PS modules in the barrel region is a Phase 2 innovation that improves tracking performance by facing the modules orthogonal to the trajectory of incident particles.

Evaluating the PS-Module Prototype

Each array of pixel sensors will be associated with a Macro Pixel ASIC (MPA). Our measurements concern the earliest prototype of this IC, the MPA-Light, six of which are arranged into a test module called the MaPSA. Each MPA-Light is bonded to an array of pixels, but the MaPSA has no strip module. Our efforts focus verifying two key parameters of the MPA-Light electronics: the timewalk and the peaking time. Timewalk is an apparent difference in the arrival time of a signal, resulting when signals of different amplitudes cross a threshold, while peaking time is the duration necessary for a signal to reach its maximum value.

Upgrading the CMS Outer Tracker

The CMS tracking detector is a silicon based detector designed to reconstruct the trajectories of charged particles in the CMS magnetic field. The current tracking detector is only designed to handle 500fb^{-1} and a pileup of about 20, and for that reason the Phase 2 CMS tracker upgrade will introduce a higher granularity and radiation harder detector, capable of handling the demands of the HL-LHC. The outer tracker will include pixel-strip (PS) modules, which will contribute to the the L1 triggering through hardware recognition of potential high p$_T$ candidates, called "stubs".

Timewalk and Peaking Time Measurements
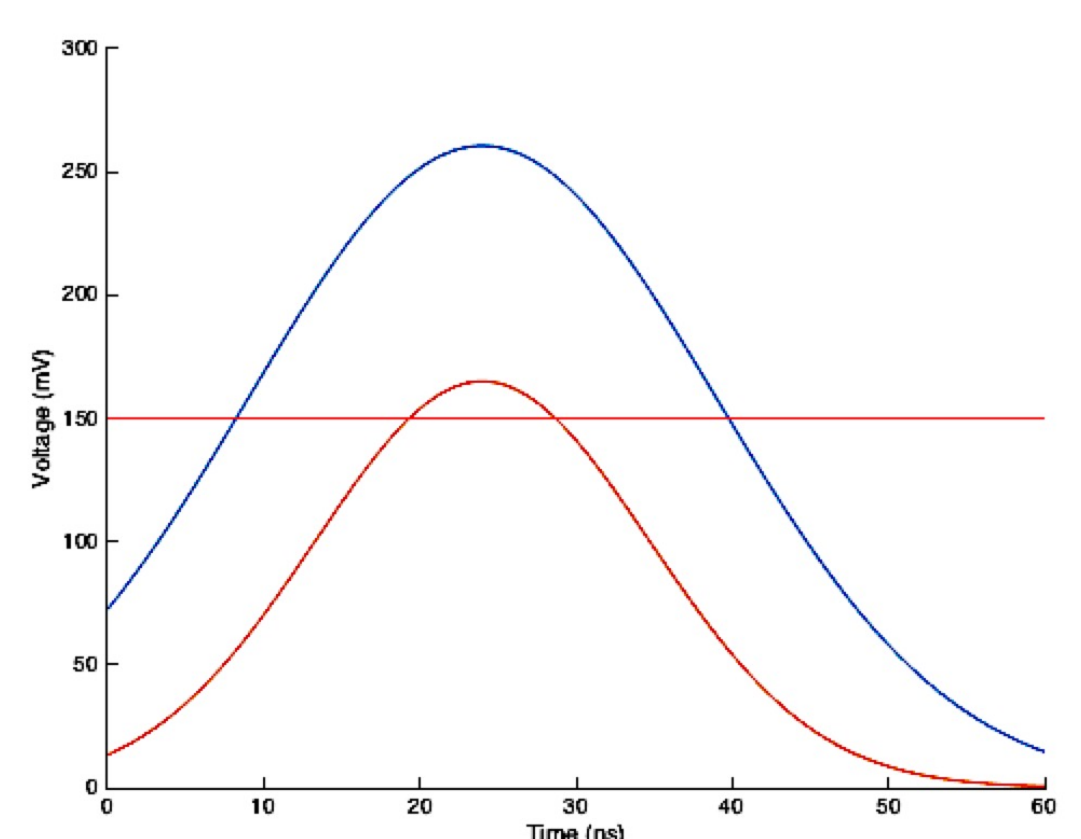
In order tor produce measurements, our setup includes:
– a 900nm picosecond laser, to generate pixel hits
– 3 stepper motors, to scan the laser in x, y, and z
– an oscilloscope, to delay the laser signal by fixed amounts

The MaPSA output provides limited analog information, but two key pieces of information are provided:
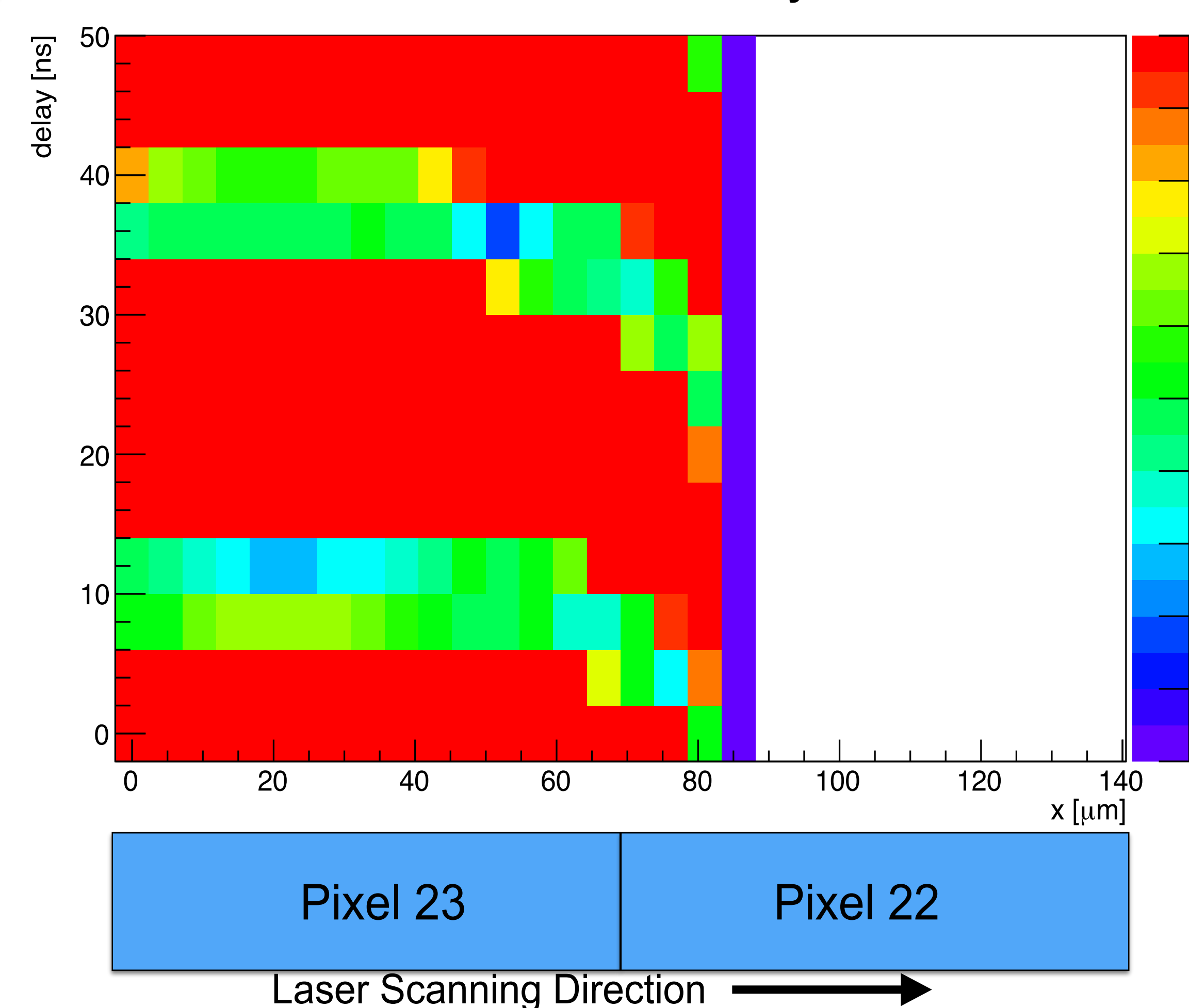– Which pixel was hit
– In what clock cycle the pixel was hit

The 40MHz clock cycle of data acquisition corresponds to the frequency of bunch crossings in the LHC and HL-LHC. We glean analog information by modifying threshold and oscilloscope time delay

Information. The plot here shows how time and voltage information localizes a point on a voltage pulse while illustrating the concepts of timewalk and peaking time.


Pulse Profile for Intensity 50%

Peaking time: The specified peaking time for the MPA-Light is 24ns. However, our preliminary measurements show that the peaking time is, in fact, greater than 30ns. Currently more measurements are underway to verify this result and to better quantify the peaking time of the device.

X-Position vs. Time Delay Pixel 23

Pixel 23 | Pixel 22

Laser Scanning Direction →

Scan in Position and Laser Delay: As the laser scans from Pixel 23 to Pixel 22, it enters a transition region where photons are shared between pixels, and the variation in signal strength leads to timewalk. This measurement illustrates a maximum timewalk of ~12ns, less than the specified timewalk (<14ns for 0.75fC-12fC signals with threshold 0.5fC). Incidentally, the bands here also show the 25ns periodicity of the clock.

Timewalk Measurement for Threshold of 80
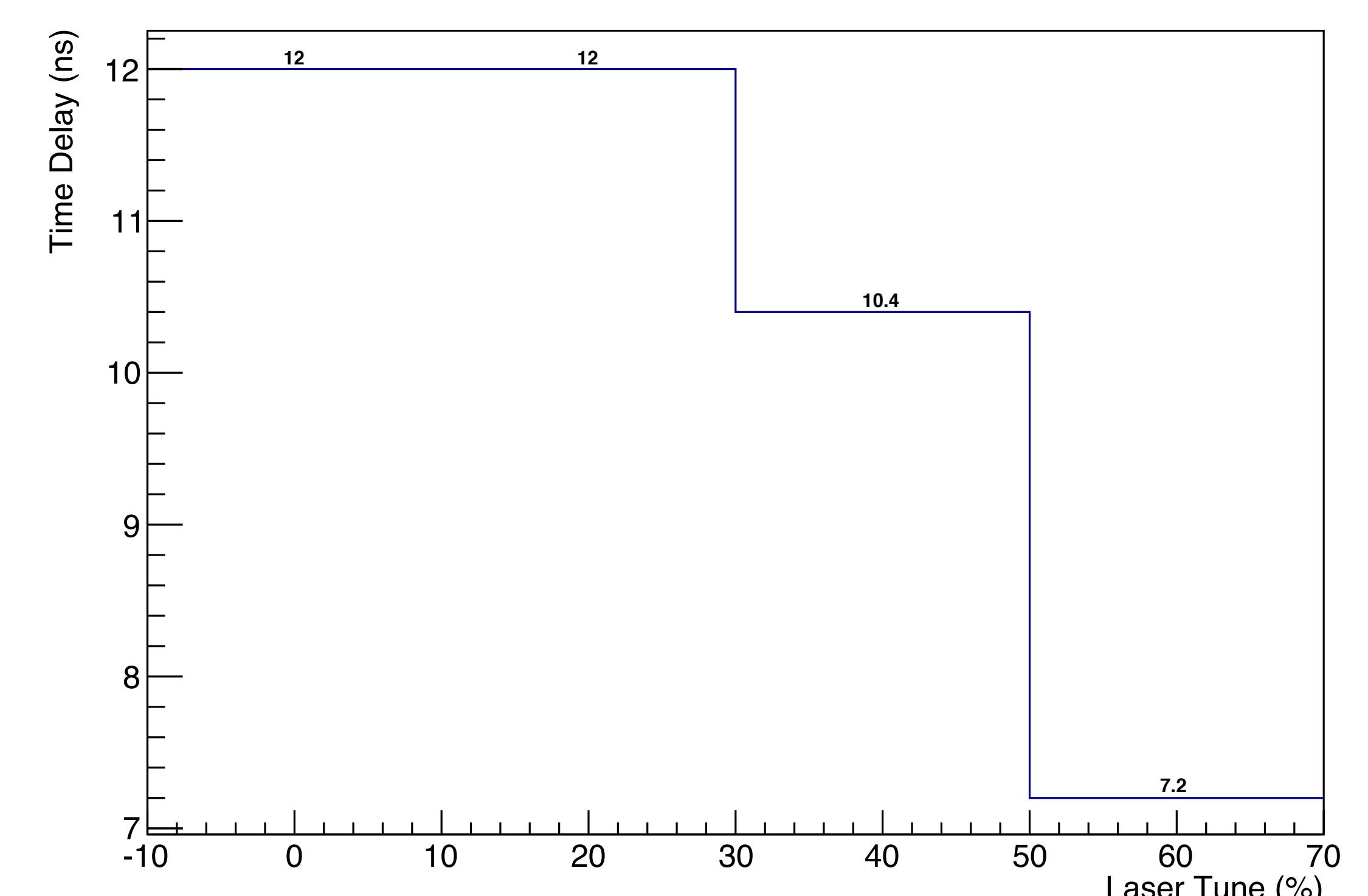
Timewalk Measurement: Here we seek to measure the timewalk for a threshold of 80·1.456mV = 116.48mV using different laser intensities. Our preliminary measurements show a timewalk of >~4.8ns for the intensities selected. This measurement must be repeated over a broader range of thresholds to better quantify the timewalk. Furthermore, the laser intensity must be correlated to signal charge in order to verify the specified value within the 0.75fC-12fC signal range.

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